| **Section 25.1** | **Properties of Stars** |
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**Key Concepts**

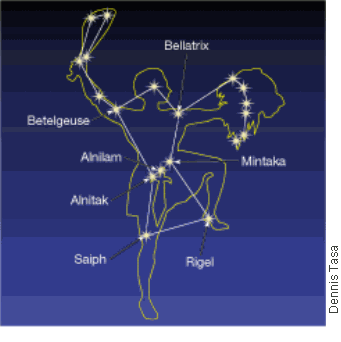
* [What can we learn by studying star properties?](javascript:openCrossRef('../ch25/ch25_s1_1.html%23lnk701.2'))
* [How does distance affect parallax?](javascript:openCrossRef('../ch25/ch25_s1_2.html%23lnk702.4'))
* [What factors determine a star’s apparent magnitude?](javascript:openCrossRef('../ch25/ch25_s1_3.html%23lnk703.3'))
* [What relationship is shown on a Hertzsprung-Russell diagram?](javascript:openCrossRef('../ch25/ch25_s1_4.html%23lnk704.2'))

**Vocabulary**

* [constellation](javascript:openCrossRef('../ch25/ch25_s1_0.html%23lnk700.2')) [binary star](javascript:openCrossRef('../ch25/ch25_s1_1.html%23lnk701.4'))
* [light-year](javascript:openCrossRef('../ch25/ch25_s1_2.html%23lnk702.6')) [apparent magnitude](javascript:openCrossRef('../ch25/ch25_s1_3.html%23lnk703.3'))
* [absolute magnitude](javascript:openCrossRef('../ch25/ch25_s1_3.html%23lnk703.5')) [main-sequence star](javascript:openCrossRef('../ch25/ch25_s1_4.html%23lnk704.3'))
* [red giant](javascript:openCrossRef('../ch25/ch25_s1_4.html%23lnk704.5')) [supergiant](javascript:openCrossRef('../ch25/ch25_s1_4.html%23lnk704.5'))
* [Cepheid variable](javascript:openCrossRef('../ch25/ch25_s1_4.html%23lnk705.2')) [nova](javascript:openCrossRef('../ch25/ch25_s1_4.html%23lnk705.3'))
* [nebulae](javascript:openCrossRef('../ch25/ch25_s1_4.html%23lnk706.1'))

The star Proxima Centauri is about 100 million times farther away from Earth than the moon. Yet, besides the sun, it is the closest star to Earth. The universe is incomprehensibly large. What is the nature of this vast universe? Do stars move, or do they remain in one place? Does the universe extend infinitely in all directions, or does it have boundaries? This chapter will answer these questions by examining the universe and the most numerous objects in the night sky—the stars.

As early as 5000 years ago, people became fascinated with the star-studded skies and began to name the patterns they saw. These patterns of stars, called [**constellations**](javascript:openGlossaryWnd('e_ga_06_constellation')), were named in honor of mythological characters or great heroes, such as Orion, shown in Figure 1.



**Figure 1 Orion** The constellation Orion was named for a hunter.

Although the stars that make up a constellation all appear to be the same distance from Earth, some are many times farther away than others. So, the stars in a particular constellation are not associated with one another in any physical way.

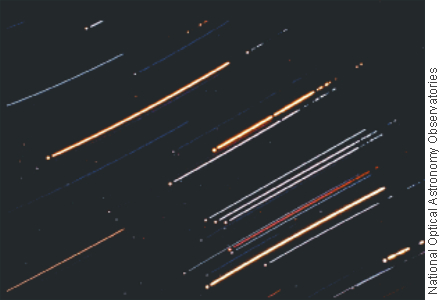
Today 88 constellations are recognized. They are used to divide the sky into units, just as state boundaries divide the United States. Every star in the sky is in, but is not necessarily part of, one of these constellations. Therefore, constellations can be used as a “map” of the night sky.

**Characteristics of Stars**

A great deal is known about the universe beyond our solar system. This knowledge hinges on the fact that stars, and even gases in the “empty” space between stars, radiate energy in all directions into space. The key to understanding the universe is to collect this radiation and unravel the secrets it holds. Astronomers have devised many ways to do just that. We will begin by examining some properties of stars, such as color, temperature, and mass.

**Star Color and Temperature**

Study the stars in Figure 2 and note their color. **Color is a clue to a star’s temperature.** Very hot stars with surface temperatures above 30,000 K emit most of their energy in the form of short-wavelength light and therefore appear blue. Red stars are much cooler, and most of their energy is emitted as longer-wavelength red light. Stars with temperatures between 5000 and 6000 K appear yellow, like the sun.

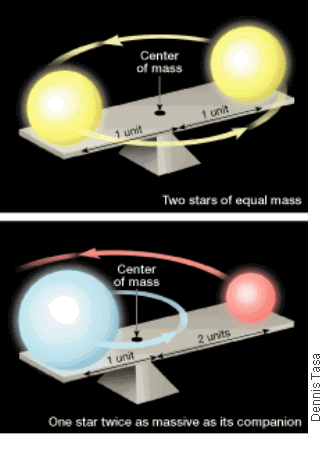


**Figure 2 Stars of Orion** This time-lapse photograph shows stars as streaks across the night sky as Earth rotates. The streaks clearly show different star colors.

**Binary Stars and Stellar Mass**

In the early nineteenth century, astronomers discovered that many stars orbit each other. These pairs of stars, pulled toward each other by gravity, are called [**binary stars**](javascript:openGlossaryWnd('e_ga_06_binarystar')). More than 50 percent of the stars in the universe may occur in pairs or multiples.

**Binary stars are used to determine the star property most difficult to calculate—its mass.** The mass of a body can be calculated if it is attached by gravity to a partner. This is the case for any binary star system. As shown in Figure 3, binary stars orbit each other around a common point called the center of mass. For stars of equal mass, the center of mass lies exactly halfway between them. If one star is more massive than its partner, their common center will be closer to the more massive one. If the sizes of their orbits are known, the stars’ masses can be determined.



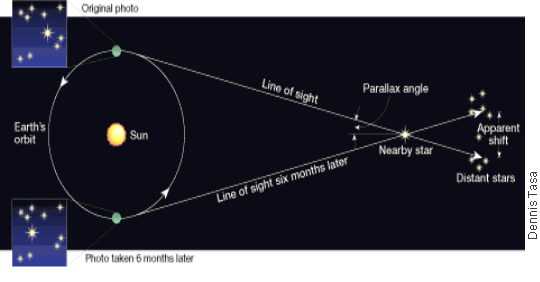
**Figure 3 Common Center of Mass A** For stars of equal mass, the center of mass lies in the middle. **B** A star twice as massive as its partner is twice as close to the center of mass. It therefore has a smaller orbit than its less massive partner.

Measuring Distances to Stars

Although measuring the distance to a star is very difficult, astronomers have developed some methods of determining stellar distances.

**Parallax**

The most basic way to measure star distance is parallax. Parallax is the slight shifting in the apparent position of a nearby star due to the orbital motion of Earth. Parallax is determined by photographing a nearby star against the background of distant stars. Then, six months later, when Earth has moved halfway around its orbit, a second photograph is taken. When these photographs are compared, the position of the nearby star appears to have shifted with respect to the background stars. Figure 4 shows this shift and the resulting parallax angle.



**Figure 4 Parallax** The parallax angle shown here is exaggerated to illustrate the principle. Because the distances to even the nearest stars are huge, astronomers work with very small angles.**Relating Cause And Effect**What caused the star to appear to shift?

**The nearest stars have the largest parallax angles, while those of distant stars are too small to measure.** In fact, all parallax angles are very small. The parallax angle to the nearest star (besides the sun), Proxima Centauri, is less than 1 second of arc, which equals 1/3600 of a degree. To put this in perspective, fully extend your arm and raise your little finger. Your finger is roughly 1 degree wide. Now imagine tracking a movement that is only 1/3600 as wide as your finger.

In principle, the method used to measure stellar distances may seem simple. But in practice, measurements are greatly complicated because of the tiny angles involved and because the sun, as well as the star being measured, also move through space. Even with today’s technology, parallax angles for only a few thousand of the nearest stars are known with certainty.

**Light-Year**

Distances to stars are so large that units such as kilometers or astronomical units are often too hard to use. A better unit to express stellar distance is the **[light-year](javascript:openGlossaryWnd('e_ga_06_lightyear')" \o "ALT G, Glossary Term, link opens in new window)**, which is the distance light travels in one year—about 9.5 × 1012or 9.5 trillion kilometers. Proxima Centauri is about 4.3 light-years away from the sun.

**Stellar Brightness**

The measure of a star’s brightness is its magnitude. The stars in the night sky have an assortment of sizes, temperatures, and distances, so their brightnesses vary widely.

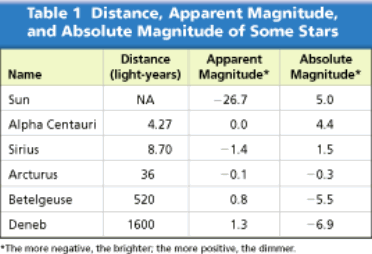
**Apparent Magnitude**

Some stars may appear dimmer than others only because they are farther away. A star’s brightness as it appears from Earth is called its **[apparent magnitude](javascript:openGlossaryWnd('e_ga_06_apparentmagn')" \o "ALT G, Glossary Term, link opens in new window)**. **Three factors control the apparent brightness of a star as seen from Earth: how big it is, how hot it is, and how far away it is.**

Astronomers use numbers to rank apparent magnitude. The larger the number is, the dimmer the star. Just as we can compare the brightness of a 50-watt bulb to that of a 100-watt bulb, we can compare the brightness of stars having different magnitudes. A first-magnitude star is about 100 times brighter than a sixth-magnitude star. Therefore, two stars that differ by 5 magnitudes have a ratio in brightness of 100 to 1. It follows, then, that the brightness ratio of two stars differing by only one magnitude is about 2.5. A star of the first magnitude is about 2.5 times brighter than a star of the second magnitude.

**Absolute Magnitude**

Astronomers are also interested in how bright a star actually is, or its **[absolute magnitude](javascript:openGlossaryWnd('e_ga_06_absltmagnitd')" \o "ALT G, Glossary Term, link opens in new window)**. Two stars of the same absolute magnitude usually do not have the same apparent magnitude because one may be much farther from us than the other. The one that is farther away will appear dimmer. To compare their absolute brightness, astronomers determine what magnitude the stars would have if they were at a standard distance of about 32.6 light-years. For example, the sun, which has an apparent magnitude of −26.7, would, if located at a distance of 32.6 light-years, have an absolute magnitude of about 5. Stars with absolute magnitude values lower than 5 are actually brighter than the sun. Because of their distance, however, they appear much dimmer. Table 1 lists the absolute and apparent magnitudes of some stars as well as their distances from Earth.



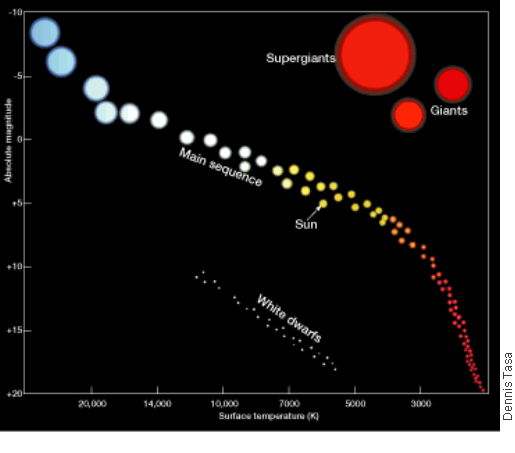
**Hertzsprung-Russell Diagram**

Early in the twentieth century, Einar Hertzsprung and Henry Russell independently developed a graph used to study stars. It is now called a Hertzsprung-Russell diagram (H-R diagram). **A Hertzsprung-Russell diagram shows the relationship between the absolute magnitude and temperature of stars.** By studying H-R diagrams, we learn a great deal about the sizes, colors, and temperatures of stars.

In the H-R diagram shown in Figure 5, notice that the stars are not uniformly distributed. About 90 percent are **[main-sequence stars](javascript:openGlossaryWnd('e_ga_06_mainseqstar')" \o "ALT G, Glossary Term, link opens in new window)** that fall along a band that runs from the upper-left corner to the lower-right corner of the diagram. As you can see, the hottest main-sequence stars are the brightest, and the coolest main-sequence stars are the dimmest.

The brightness of the main-sequence stars is also related to their mass. The hottest blue stars are about 50 times more massive than the sun, while the coolest red stars are only 1/10 as massive. Therefore, on the H-R diagram, the main-sequence stars appear in decreasing order, from hotter, more massive blue stars to cooler, less massive red stars.

Above and to the right of the main sequence in the H-R diagram lies a group of very bright stars called **[red giants](javascript:openGlossaryWnd('e_ga_06_redgiant')" \o "ALT G, Glossary Term, link opens in new window)**. The size of these giants can be estimated by comparing them with stars of known size that have the same surface temperature. Objects with equal surface temperatures radiate the same amount of energy per unit area. Therefore, any difference in the brightness of two stars having the same surface temperature is due to their relative sizes. Some stars are so large that they are called **[supergiants](javascript:openGlossaryWnd('e_ga_06_supergiant')" \o "ALT G, Glossary Term, link opens in new window)**. Betelgeuse, a bright red supergiant in the constellation Orion, has a radius about 800 times that of the sun.



**Figure 5 Hertzsprung-Russell Diagram** In this idealized chart, stars are plotted according to temperature and absolute magnitude.

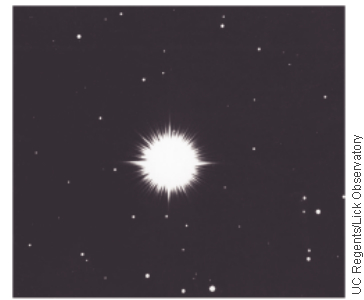
Stars in the lower-central part of the H-R diagram are much fainter than main-sequence stars of the same temperature. Some probably are no bigger than Earth. This group is called white dwarfs, although not all are white.

Soon after the first H-R diagrams were developed, astronomers realized their importance in interpreting stellar evolution. Just as with living things, a star is born, ages, and dies. After considering some variable stars and the nature of interstellar matter, we’ll return to the topic of stellar evolution.

**Variable Stars**

Stars may fluctuate in brightness. Some stars, called **[Cepheid variables](javascript:openGlossaryWnd('e_ga_06_cepheidvarbl')" \o "ALT G, Glossary Term, link opens in new window)**, get brighter and fainter in a regular pattern. The interval between two successive occurrences of maximum brightness is called a light period. In general, the longer the light period of a Cepheid, the greater its absolute magnitude is. Once the absolute magnitude is known, it can be compared to the apparent magnitude of the Cepheid. Measuring Cepheid variable periods is an important means of determining distances within our universe.

A different type of variable is associated with a **[nova](javascript:openGlossaryWnd('e_ga_06_nova')" \o "ALT G, Glossary Term, link opens in new window)**, or sudden brightening of a star. During a nova eruption, the outer layer of the star is ejected at high speed. A nova, shown in Figure 6, generally reaches maximum brightness in a few days, remains bright for only a few weeks, then slowly returns in a year or so to its original brightness. Only a small amount of its mass is lost during the flare-up. Some stars have experienced more than one such event. In fact, the process probably occurs repeatedly.





**Figure 6 Nova** These photographs, taken two months apart, show the decrease in brightness that follows a nova flare-up.

Scientists think that novas occur in binary systems consisting of an expanding red giant and a nearby hot white dwarf. Hydrogen-rich gas from the oversized giant is transferred by gravity to the white dwarf. Eventually, the added gas causes the dwarf to ignite explosively. Such a reaction rapidly heats and expands the outer layer of the hot dwarf to produce a nova. In a relatively short time, the white dwarf returns to its prenova state, where it remains inactive until the next buildup occurs.

**Interstellar Matter**

Between existing stars is “the vacuum of space.” However, it is not a pure vacuum, for there are clouds of dust and gases known as **[nebulae](javascript:openGlossaryWnd('e_ga_06_nebula_a')" \o "ALT G, Glossary Term, link opens in new window)**. If this interstellar matter is close to a very hot star, it will glow and is called a bright nebula. The two main types of bright nebulae are emission nebulae and reflection nebulae.

Emission nebulae consist largely of hydrogen. They absorb ultraviolet radiation emitted by a nearby hot star. Because these gases are under very low pressure, they emit this energy as visible light. This conversion of ultraviolet light to visible light is known as fluorescence. You can see this effect in fluorescent lights. Reflection nebulae, as the name implies, merely reflect the light of nearby stars. Reflection nebulae are thought to be composed of dense clouds of large particles called interstellar dust.

Some nebulae are not close enough to a bright star to be lit up. They are called dark nebulae. Dark nebulae, such as the one shown in Figure 7, can easily be seen as starless regions when viewing the Milky Way.



**Figure 7 Dark Nebula** The Horsehead Nebula is found in the constellation Orion.

Although nebulae appear very dense, they actually consist of thinly scattered matter. Because of their enormous size, however, their total mass may be many times that of the sun. Astronomers study nebulae because stars and planets form from this interstellar matter.

**SECTION 25.1 Assessment**

# Reviewing Concepts

(1)What can astronomers learn by studying a star’s color?

(2)Binary stars can be used to establish what property of stars?

(3)How does distance affect parallax?

(4)What factors determine a star’s apparent magnitude?

(5)The H-R diagram shows the relationship between what two factors?

# ~~Critical Thinking~~

~~(6)~~**~~Problem Solving~~**~~How many times brighter is a star with a magnitude of 7 than a star with a magnitude of 12?~~